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(NASA-CR-144667) EVALUATION PROGRAM FOR
SECONDARY SPACECRAFT CELLS: INITIAL
EVALUATION TESTS OF GENERAL ELECTRIC COMPANY
6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT
CELLS FOR THE (Naval Weapons Support Center, G3/44

EVALUATION PROGRAM for SECONDARY SPACECRAFT CELLS

INITIAL EVALUATION TESTS
OF
GENERAL ELECTRIC COMPANY
6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
FOR THE
IMPROVED ~~ITROS~~ OPERATIONAL SATELLITE (ITOS)

prepared for
GODDARD SPACE FLIGHT CENTER

CONTRACT S-23404-G



WEAPONS QUALITY ENGINEERING CENTER

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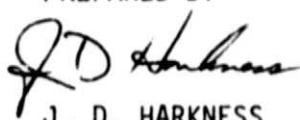
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6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
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IMPROVED TITROS OPERATIONAL SATELLITE (ITOS)

WQEC/C 75-164

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REPORT BRIEF

INITIAL EVALUATION TESTS
OF
GENERAL ELECTRIC COMPANY
6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
FOR THE
IMPROVED TIROS OPERATIONAL SATELLITE (ITOS)

Ref: (a) NASA Purchase Order S-53742AG
(b) Initial Evaluation Test Procedure for Nickel-Cadmium Sealed
Sealed Space Cells: NADC 3053-TP324 of 10 April 1973

I. TEST ASSIGNMENT BRIEF

A. The purpose of this evaluation test program is to insure that all cells put into the life cycle program are of high quality by the screening of cells found to have electrolyte leakage, internal shorts, low capacity, or inability of any cell to recover its open-circuit voltage above 1.150 volts during the internal short test.

B. The six cells were provided by the National Aeronautics and Space Administration, Goddard Space Flight Center, to NAD Crane for evaluation on life test. The cells were from the same lot as those procured by RCA under NASA contract NAS 5-10306. The cells were manufactured by General Electric Company, Gainesville, Florida, according to RCA's specification 2272642, drawing number 2278372 for the Improved TIROS Operational Satellite (ITOS). The cells were identified by General Electric's catalog number 42B006AB49. Testing was funded in accordance with reference (a).

C. Test limits specify those values in which a cell is to be terminated from a particular charge or discharge. Requirements are referred to as normally expected values based on past performance of aerospace nickel-cadmium cells with demonstrated life characteristics. A requirement does not constitute a limit for discontinuance from test.

II. SUMMARY OF RESULTS

A. The cell containers had a convex contour, in which the average thickness of the cells was .008 inches thicker at the maximum thickness when compared to the minimum thickness, which was the edge of the container. Following test, three cells indicated an increase in plate stack thickness (.001) while one cell indicated a decrease (.001).

B. One cell delivered 53% of capacity input during discharge of the charge efficiency test, in which the requirement was 55%.

C. The average cell voltage at the end of one week open-circuit, during the charge retention test, was 1.307 volts. Average capacity output was 7.6 ampere-hours following the open-circuit stand period.

D. The 24-hour average cell voltage following a 16-hour short period, was 1.205 volts.

III. RECOMMENDATIONS

A. Manufacturing processes and controls should be such as to prevent swelling of the plate stack, thereby preventing cell case distortion.

B. It was recommended that these cells be placed on life test simulating that which the spacecraft will require of the flight batteries.

C. On 5 May 1975, one 5-cell pack (Pack 7D) began life testing on a 1.92-hour orbit (1.44-hour charge) with a voltage limit control (1.453 V/C) at 20°C and a depth-of-discharge of 29.6%.

RESULTS OF
INITIAL EVALUATION TESTS
OF
GENERAL ELECTRIC COMPANY
6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
FOR THE
IMPROVED TIROS OPERATIONAL SATELLITE (ITOS)

I. TEST CONDITIONS AND PROCEDURE

A. All evaluation tests were performed at room ambient (RA) pressure and temperature ($25^{\circ} \pm 2^{\circ}\text{C}$), with discharges at the 2-hour rate, and in accordance with reference (b), unless otherwise specified, and consisted of the following:

1. Phenolphthalein leak tests (2).
2. Three capacity tests, third at 20°C , with internal resistance measurements during second charge/discharge.
3. Charge retention test, 20°C .
4. Internal short test.
5. Charge efficiency test, 20°C .
6. Overcharge tests, 0° and 35°C .
7. Phenolphthalein leak test.

(See Appendix I for summary of test procedure.)

II. CELL IDENTIFICATION AND DESCRIPTION

A. The six cells were identified by the manufacturer's catalog number, 42B006AB49-G1, lot number 01, and had serial numbers 01400186-125 to 130. The cells did not have pressure gauges.

B. The 6.0 ampere-hour cell is rectangular with an average weight and physical dimensions as follows:

| Weight (g) | Overall Height (In) | Minimum | Length (In) | | | Width (In) |
|---------------|------------------------|---------|---------------------|----------------------|----------------------|---------------|
| | | | Pre-Test Maximum | Post Test Maximum | Post Test Maximum | |
| 274.9 | 3.565 | .823 | .831 | .831 | .831 | 2.138 |

C. The cell containers and covers are made of stainless steel. The positive and negative terminals are insulated from the cell cover by ceramic seals and protrude through the cover as solder-type terminals.

III. RESULTS--The following was condensed from Table I through VI.

A. The cell container had a convex contour, in which the average thickness of the cells was .008 inches thicker at the maximum thickness when compared to the minimum thickness, which was the edge of the container. Following test, 3 cells indicated an increased in plate stack thickness (.001) while one cell indicated a decrease (.001).

B. One cell, S/N 127, delivered 53% of capacity input during discharge of the charge efficiency test, in which the requirement was 55%.

c. Average end-of-charge (EOC) voltages and capacity output in ampere-hours (ah) were as follows:

| <u>Charge</u> | <u>Volts</u> | <u>ah Out</u> |
|-----------------------------|--------------|---------------|
| c/20 for 48 hours at 25°C | 1.421 | 8.8 |
| c/10 for 24 hours at 25°C | 1.432 | 8.5 |
| c/10 for 24 hours at 20°C | 1.448 | 8.4 |
| c/10 for 24 hours at 20°C* | 1.452 | 7.6 |
| c/40 for 20 hours at 20°C** | 1.368 | 1.67 |
| c/20 for 60 hours at 0°C | 1.475 | 7.7 |
| c/10 for 24 hours at 35°C | 1.382 | 6.5 |

* Charge retention test.

** Charge efficiency test, 3 ah input.

D. Average Internal Resistance Measurements (milliohms):

| <u>Measurement Taken</u> | <u>Resistance</u> |
|--|-------------------|
| 30 Min before end of charge (Cycle 1) | 3.80 |
| 1 Hr after start of discharge (Cycle 2) | 3.83 |
| 2 Hrs after start of discharge (Cycle 2) | 3.85 |

E. The average cell voltage at the end of 1 week open-circuit, during the charge retention test, was 1.307 volts.

F. The 24-hour average cell voltage following a 16-hour short period, was 1.205 volts.

APPENDIX I

APPENDIX I

I. TEST PROCEDURE

A. Phenolphthalein Leak Tests:

1. This test is a determination of the condition of the welds and ceramic seals on receipt of the cells and following the last discharge of the cells (Cycle #7).

2. The cells were initially checked with a one-half of one percent phenolphthalein solution applied with a cotton swab and then placed in a vacuum chamber and exposed to a vacuum of 40 microns of mercury or less for 24 hours. Upon removal they were rechecked for leaks and then received a final check following test completion. The requirement is no red or pink discoloration which indicates a leak.

B. Capacity Tests:

1. The capacity test is a determination of the cells' capacity at the C/2 discharge rate to 0.75 volt per cell, where C is the manufacturer's rated capacity. This type discharge follows all charges of this evaluation test.

2. The charges for the capacity tests are as follows:

a. C/20, 48 hours, room ambient (RA), Cycle 0, with a test limit of 1.52 volts or pressure of 100 psia.

b. C/10, 24 hours, RA, Cycle 1, with a test limit of 1.52 volts or 100 psia pressure and a requirement of maximum voltage (1.48) or pressure (65 psi).

c. C/10, 24 hours, 20°C, Cycle 2, with the same limits and requirements as the charge of Cycle 1.

C. Internal Resistance:

1. Measurements are taken across the cell terminals 1/2 hour before the end-of-charge (EOC) on Cycle 1 and 1 and 2 hours after the start-of-discharge of Cycle 2. These measurements were made with a Hewlett-Packard milliohmmeter (Model 4328A).

D. Special Charge Retention Test, 20°C:

1. This test is to establish the capacity retention of each cell following a 7-day open-circuit-stand in a charge mode.

2. The cells are charged at C/10 for 24 hours with a test limit of 1.52 volts or 100 psia pressure. They then stand on open-circuit for 7 days, with the requirement that the open-circuit voltage of each cell, following this period, is within +5 millivolts of the average cell voltage. The cells are then discharged and 80 percent capacity out of the obtained in Cycle 3 is required.

E. Internal Short Test:

1. This test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to element in handling or assembly.

2. Following completion of the third capacity discharge, the cells are shunted with a 0.5-ohm, 3-watt resistor for 16 hours. At the end of 16 hours the resistors are removed and the cells stand on open-circuit-voltage (OCV) for 24 hours. A minimum voltage of 1.15 is required at the end of the 24 hours.

F. Charge Efficiency Test, 20°C:

1. This test is a measurement of the cells' charge efficiency when charged at a low current rate.

2. The cells are charged at C/40 for 20 hours with a test limit of 1.52 volts or 100 psia pressure. They are then discharged and the requirement is that the minimum capacity out equals 55 percent of capacity in during the preceding charge.

G. Overcharge Test #1, 0°C:

1. The purpose of this test is to determine the degree to which the cells will maintain a balanced voltage, and to determine the cells' capability to be overcharged without overcharging the negative electrode.

2. The cells are charged at C/20 for 60 hours. The test limits are cell voltages of 1.56 or greater for a continuous time period of 2 hours or pressures of 100 psia. The requirement is a voltage of 1.520 or a pressure of 65 psia. The cells are then discharged and 85 percent capacity out of that obtained in Cycle 3 is required.

H. Overcharge Test #2, 35°C:

1. This test is a measurement of the cells' capacity at a higher temperature when compared to its capacity at 20°C. This test also determines the cells' capability of reaching a point of pressure equilibrium; oxygen recombination at the negative plate at the same rate it is being generated at the positive plate.

2. The cells are charged C/10 for 24 hours with a test limit of .52 volts or 100 psia pressure and a requirement of 1.45 volt or 65 psia pressure. The cells are then discharged with a requirement that capacity out equals 55 percent capacity out as obtained in Cycle 3.

TABLE I
MEASUREMENT AND LEAK TEST DATA

| SERIAL NUMBER | WEIGHT (Grams) | HEIGHT (Inches) | LENGTH (Inches) | WIDTH (Inches) | PHENOLPHTHALEIN LEAK TESTS | | | | | |
|------------------|-------------------|--------------------|-----------------|-------------------|----------------------------|-------|-------------|-----------|-----------|-----------|
| | | | | | INITIAL | | POST HI VAC | | POST TEST | |
| | | | | | Terminals | Other | Terminals | Other | Terminals | Other |
| | | | | | + | - | + | - | + | - |
| 125 | 2.72.7 | 3.562 | .819 | .8225 | .826 | 2.140 | | | | |
| 126 | 2.74.3 | 3.560 | .822 | .830 | .831 | 2.136 | | | | |
| 127 | 2.74.6 | 3.564 | .823 | .832 | .832 | 2.135 | N/C LEAKS | N/C LEAKS | N/C LEAKS | N/C LEAKS |
| 128 | 2.75.1 | 3.566 | .829 | .838 | .837 | 2.145 | | | | |
| 129 | 2.77.1 | 3.568 | .821 | .829 | .829 | 2.140 | | | | |
| 130 | 2.75.6 | 3.572 | .822 | .831 | .832 | 2.133 | | | | |

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TABLE II
Capacity Data

| SERIAL NUMBER | Capacity Test 1 END-OF-CHARGE | | | Capacity Test 2 END-OF-DISCHARGE | | | Capacity Test 3 (20°C) END-OF-CHARGE | | |
|------------------|----------------------------------|-------------------------|-----------------|-------------------------------------|-------------------------|-----------------|---|-------------------------|-----------------|
| | CELL (Volts) | AUX ELECT (Volts) | PRESS (PSIA) | CELL CAPAC- ITy (ah) | AUX ELECT (Volts) | PRESS (PSIA) | CELL CAPAC- ITy (ah) | AUX ELECT (Volts) | PRESS (PSIA) |
| 125 | 1.419 | N/A | 8.6 | N/A | 1.433 | N/A | 8.6 | N/A | 8.5 |
| 126 | 1.418 | " | 8.6 | " | 1.430 | " | 8.5 | 1.448 | 8.4 |
| 127 | 1.420 | " | 8.7 | " | 1.431 | " | 8.5 | 1.442 | 8.2 |
| 128 | 1.421 | " | 8.7 | " | 1.432 | " | 8.5 | 1.448 | 8.4 |
| 129 | 1.422 | " | 8.8 | " | 1.432 | " | 8.5 | 1.445 | 8.4 |
| 130 | 1.425 | " | 8.6 | " | 1.435 | " | 9.6 | 1.452 | 8.5 |

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TABLE III
INTERNAL RESISTANCE AND SHORT TEST DATA

9ND-NADC (SP 11/73)

TABLE IV
CHARGE RETENTION TEST DATA

WOEC/C 75-164

TABLE V
Charge Efficiency and Overcharge Data

| SERIAL NUMBER | Charge Efficiency, 20°C | | END-OF-CHARGE | | Overcharge Test (0°) | | Overcharge Test (35°C) | | Overcharge Test (35°C) | | END-OF-CHARGE | AUX CAPACITY (ah) | PRESSURE (PSIA) | CELL ELECT (Volts) | AUX ELECT (Volts) | PRESSURE (PSIA) | CELL ELECT (Volts) | AUX ELECT (Volts) | PRESSURE (PSIA) | CELL ELECT (Volts) | AUX ELECT (Volts) | PRESSURE (PSIA) |
|---------------|-------------------------|-------------------|-------------------|------------------|----------------------|-------------------|------------------------|------------------|------------------------|-------------------|---------------|-------------------|-----------------|--------------------|-------------------|-----------------|--------------------|-------------------|-----------------|--------------------|-------------------|-----------------|
| | CELL ELECT (Volts) | AUX ELECT (Volts) | CELL PRESS (PSIA) | AUX PRESS (PSIA) | CELL ELECT (Volts) | AUX ELECT (Volts) | CELL PRESS (PSIA) | AUX PRESS (PSIA) | CELL ELECT (Volts) | AUX ELECT (Volts) | | | | | | | | | | | | |
| 125 | 1.368 | N/A | N/A | 1.65 | N/A | N/A | 1.475 | N/A | 7.6 | N/A | N/A | N/A | N/A | 6.4 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| 126 | 1.368 | " | " | 1.70 | " | " | 1.473 | " | 7.7 | " | " | " | " | 6.5 | " | " | " | " | " | " | " | |
| 127 | 1.368 | " | " | 1.60 | " | " | 1.477 | " | 7.5 | " | " | " | " | 6.3 | " | " | " | " | " | " | " | |
| 128 | 1.369 | " | " | 1.70 | " | " | 1.474 | " | 7.7 | " | " | " | " | 6.5 | " | " | " | " | " | " | " | |
| 129 | 1.369 | " | " | 1.65 | " | " | 1.473 | " | 7.6 | " | " | " | " | 6.5 | " | " | " | " | " | " | " | |
| 130 | 1.369 | " | " | 1.70 | " | " | 1.477 | " | 7.6 | " | " | " | " | 6.6 | " | " | " | " | " | " | " | |

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